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MANAGEMENT OF WHEAT PRODUCTION IN SALINE SOILS THROUGH MULTI-STRAIN BACTERIAL INOCULATION

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Salinity induced stress plays an authoritative role in declining the yield of cereal crops. Multi-strain inoculation with ACC deaminase plant growth promoting rhizobacteria (PGPR) can alleviate salinity persuaded stress on plant growth and yield. To the role of ACC deaminase PGPR (multi-strain), a pot experiment was conducted on wheat under 3 artificially induced salinity levels (3, 6 and 9 dsm^{-1}) in combination with recommended NPK fertilizers (RNPKF). Results indicated that W6×W10×PsJN + RNPKF was the best treatment that significantly enhanced plant height, spike length, root length, root dry weight and shoots dry weight as compared to control. Straw, biological and economic yields were also amplified as compared to the control as a result of the treatment, W6×W10×PsJN + RNPKF. Similar improvements were also noted in grains and shoot, N and P concentrations respectively where W6×W10×PsJN was applied in combination with RNPKF. It is concluded that multi-strain PGRR inoculation with RNPKF could be an effective strategy to mitigate salinity stress by controlling the ethylene accretion in wheat plants. Single strain inoculation with RNPKF moreover enhanced the growth and yield traits but multi-strain inoculation with RNPKF is the best strategy to mitigate salinity stress.
Keywords: Multi strains, PGPR inoculation, salinity stress, ethylene accretion, productivity

INTRODUCTION

In arid and semi-arid regions of the world, one of the major agricultural problems is an accumulation of extreme soluble salts in upper soil horizons. Salinity is important abiotic stress (Debez *et al.,* 2006; Koyro, 2006). Brackish irrigation water (Shakirova *et al.,* 2003), high temperature, less rainfall (Ahmad *et al.,* 2003), poor soil drainage and improper methods of irrigation are major causes of soil salinity development. More than 20% arid and semi-arid zone soils have already become saline (Muhling and Lauchli, 2003).

Seed sprouting, seedling growth, root development (Neumann, 1995), leaf number, leaf expansion (El-Hendawy *et al.,* 2005), flowering, and fruit set are adversely affected due to salinity. The reasons behind may be the osmotic shock, ionic imbalance and interruption in metabolic processes (Zhu *et al.,* 1997*;* Arora *et al.,* 2008). Salinity not only damages the crop yield but also deteriorates the quality of the produce. Most of the crops cultivated under saline conditions produce and store fewer carbohydrates and proteins in their body (Parida *et al.,* 2002).

High demand for foodstuff due to snowballing population has made the cultivation of saline soils a necessity of time by adopting low cost and easily affordable technologies. In near past, the research showed that inoculation of plant growth promoting rhizobacteria (PGPR) improve the germination, seedling growth and fresh biomass of plants cultivated in saline soils (Afrasayab *et al.,* 2010). The PGPR are present in the plant rhizosphere, sometimes by making a complex interaction with the roots of plants (Sylvia *et al.,* 1999). Some of the PGPR endorse the development of plants through the biosynthesis of auxins and gibberellins as well as control pest attack by the production of 2, 4-diacetylphloroglucinol (2, 4-DAPG) and phenazine (Shanahan *et al.,* 1992; Burkhead *et al.,* 1994).

It is well documented that abiotic stress increases the level of ethylene in plants. Some of the PGPR also contain an enzyme 1-aminocyclopropane-1-carboxylate deaminase (ACC-deaminase) which reduces the increased level of ethylene. The ACC-deaminase actually converts the 1-aminocyclopropane-1-carboxylic acid (ACC, an immediate precursor of ethylene biosynthesis in higher plants) into ammonia and a-ketobutyrate instead of ethylene (Hall *et al.,* 1996). A variety of rhizobacteria have been found to possess ACC-deaminase, which help in mitigating the effect of abiotic stress on different crops (Zafar-ul-Hye *et al.,* 2015). The reduction in ethylene (as lower as 10 μg L−1) would likely to improve the growth of roots in plant sunder salt-affected soils (Zafar-ul-Hye *et al.,* 2007, 2014; Jalili *et al.,* 2009).

Wheat (*Triticum aestivum* L.) is considered as the sovereign of cereal crops and a staple food in most parts of the world. Wheat- grain is a rich source of carbohydrates and proteins

(approx. 75%) with a minor quantity of fats (1-3%). Additionally, wheat grain is virtuous of vitamin B, thiamin, riboflavin- niacin and vitamin E (Brigid, 2004). Therefore, the objective of the current study was to explore the role of multi-strain inoculation with PGPR containing ACC-deaminase under various soil salinity echelons on growth and yield of wheat (*T. aestivum* L.). Although the impact of PGPR on crops growth under saline conditions has already been studied novelty of our work is the use of multi-strain inoculation of plant growth promoting rhizobacteria possessing ACC-deaminase for wheat productivity at different salinity levels. The experiment was planned with the hypothesis that the multi-strain inoculation would grant the wheat plants more resistance against salinity and consequently promote growth and productivity as compared to single strain inoculation and/or uninoculated conditions.

MATERIALS AND METHODS

A pot trial was conducted at the Field area of Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University Multan, Pakistan (30°15'31.1 "N, 71°30'50.9 "E). The climatic condition of the research area was sub-tropical to semi-arid. There were 8 treatments (control, W6, W10, PsJN, W6 x W10, W6 x PsJN, W10 x PsJN and W6 x W10 x PsJN) under 3 salinity levels (3, 6 and 9 dSm^{-1}) with 3 replications having 2 factorial arrangements following complete randomized design (CRD).

***Pot preparation*:** Plastic posts were used in the experiment having the capacity of carrying 10 kg soil. No hole in the bottom was made for drainage. The soil used in the experiment was categorized as silty clay loam in texture by the textural triangle. In each pot having 8 kg soil, macronutrients (nitrogen, phosphorus, and potassium) were applied according to recommended rates as 1.04g urea, 2g diammonium phosphate (DAP) and 0.4gsulphate of potash (SOP).

***Artificially salinity induction*:** The electrical conductivity (EC) of soil was 3 dSm^{-1}. Further 2 salinity levels in soil samples were artificially induced at 6 dSm^{-1} (6.81 g/ 8 kg soil) and 9 dSm^{-1} (13.6 g/ 8 kg soil) by mixing Na_2SO_4 salt.

***Bacterial strainsand seed inoculation*:** Three strains (W6×W10× PsJN) of PGPR having ACC deaminase positive bacteria were used in the experiment. All the three strains were acquired by Soil Microbiology and Biochemistry Laboratory, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan. The carrier material was peat collected from the local nursery.

***Preparation of salt minimal medium*:** Composition of DF salt minimal medium used was included, KH_2PO_4 = 4 g/L, Na_2HPO_4 = 6 g/L, $MgSO_4.7H_2O$ =0.25 g/L, $FeSO_4.7H_2O$ = 1 mg/L, H_3BO_3 = 10 µg/L, $MnSO_4$= 10 µg/L, $ZnSO_4$ = 70 µg/L, $CuSO_4$ = 50 µg/L, MoO_3 =10 µg/L, glucose = 10 g/L, gluconic acid = 2 g/L, citric acid= 2 g/L, distilled water = 1 L and ACC = 5 mM/0.66 g/L (Dworkin and Foster, 1958). No other nitrogen source was added. The seeds were inoculated according to the reformed protocol described by (Sharma *et al.*, 2003). Broth cultures were kept at a temp of 28±1°C with continuous shaking at 100 rpm (revolution per minute) for 72 h. The paste used for seed coating was prepared by mixing a sugar solution with the bacterial broth cultures and the addition of the sterilized peat and clay.

***Seeds sowing and harvesting*:** Seeds of *T. aestivum L.* (FSD – 2008) were obtained from Soil Microbiology and Biochemistry Laboratory, Institute of Soil and Environmental Science, University of Agriculture Faisalabad, Pakistan. In each pot, 20 seeds were sown manually. After germination 5 plants in each pot were maintained by thinning. The harvesting of plants was done at maturity after 110 days of sowing.

***Soil analyses*:** After calibrating pH (JENWAY-3510) and EC (BANTE-DDS 12DW) meters the pH and EC of soil were analyzed by making 1:5 soil-water ratio (Schofield and Taylor, 1995). Textural class of soil was verified by using a hydrometer and USDA textural triangle (Moodie *et al.*, 1959). Analysis of phosphorus in soil was done on spectrophotometer by following Olsen and Sommers (1982) method. Potassium was analyzed on flame photometer. The pre-sowing soil attributes are given in Table 1.

***Plant analyses*:** Standard methods were used for data collection regarding plant height (cm), spike length (cm), root length (cm), root and shoot dry weights (g), no. of tillers per plant, no. of spikelet's per plant, no. of grains per plant, economic, straw and biological yields (g). Initially, digestion of plant and grains samples for nitrogen, phosphorus and potassium determination was done by wet digestion methods (Wolf, 1982). Kjeldahl's apparatus was used for the determination of nitrogen content in grains and shoot (Jackson, 1962).

Table 1. Physical and chemical analysis of pre-experimental soil.

Parameters	Values	Unit
Physical analysis		
Sand	50	%
Silt	27	%
Clay	22	%
Textural class	Sandy clay loam	
Chemical analysis		
pH	8.70	-
EC	3.00	dSm^{-1}
Total Nitrogen	0.08	%
Olsen's P PPPhosphorus	7.23	µg g^{-1}
Extractable P Potassium	97.0	µg g^{-1}

Olsen's method was used for phosphorus determination by Spectrophotometer (HITACHI U-2000) at a 610nm wavelength (Watanabe and Olsen, 1965). Potassium was

determined by using Jenway PFP-7 flame photometer (Richards, 1954).

***Statistical analyses*:** For statistical analyses, statistical computer software package SPSS was used (SPSS Inc. Released 2009 PASW Statistics for Windows, Version 18.0 Chicago) to analyze all parameters by 2 ways ANOVA. LSD ($P \leq 0.05$) test was applied for differentiation.

RESULTS

The results revealed that multi-strain inoculation significantly modified the wheat plant height, spike length, root length and straw yield under different EC levels (Table 2). The treatment W6×W10×PsJN + recommended NPK fertilizers (RNPKF) under different levels of EC gave best results in case of plant height (Table 2A), root length (Table 2C) and straw yield (Table 2D) while in case of spike length (Table 2B) W6×W10×PsJN + RNPKF, W10 + RNPKF and W6 × W10 + RNPKF performance was best. On an average, as associated to rheostat extreme rise in plant height that was noted in treatments of W6×W10×PsJN + RNPKF (23%) and W6 + RNPKF (19%) which were statistically similar to each other but different to all other treatments. In spike length, the treatments W6×W10 + RNPKF and W6×W10×PsJN + RNPKF were statistically at par with each other but ominously well as associated to all other treatments. The highest increase in root length (40%) and straw yield (96%) was noted in W6×W10×PsJN + RNPKF in comparison to control, which was statistically different to all other treatments. Such improvement in plant height, root length, straw yield and spike length at the higher level of salinity (6 dSm-1 and 9 dSm-1 EC) was also noted which might be due to the alleviation of salinity stress by multi strains PGPR.

The dry weight (Shoots), dry weight (root), economic yield or 1000-grains weight were also expressively increased in wheat plants cultivated with inoculation of multi strains PGPR + RNPKF under various salinity levels (Table 3). On an average maximum increase in economic yield (170%) and 1000-grains weight (36%) was found in the treatment of W6×W10×PsJN + RNPKF as compared to control which was suggestively different to all other treatments. In case of shoot dry weight W6×W10×PsJN + RNPKF showed an increase of 63% as compared to control which was the statistically alike to W10×PsJN + RNPKF and W6×W10× + RNPKF. Similarly, W6×W10×PsJN + RNPKF also showed best results in case of root dry weight but statistically at par to

Table 2. Effect of multi-strain PGPR inoculation with recommended dose of NPK fertilizer (RNPKF) under various salinity levels (3, 6 and 9 dS m^{-1}) on wheat.

	Inoculated PGPR strains				**Electrical Conductivity of soil (dSm^{-1})**			
	3	**6**	**9**	**Mean**	**3**	**6**	**9**	**Mean**
	A				B			
Control + (RNPKF)	59.2gh	54.8j	49.2 k	54.4E	6.06k	6.00ij	5.41I	5.82D
W6 + (RNPKF)	72.3ab	63.1ef	59.1gh	64.8AB	8.80c	7.86efg	7.06hi	7.90BC
W10 + (RNPKF)	68.9bc	64.3de	59.1gh	64.1BC	8.26cdef	7.73fg	6.73ij	7.57C
PON + (RNPKF)	68.7bc	59.2gh	58.7ghi	62.2CD	8.30cde	8.00cd	6.46jk	7.58C
W6xWIO + (RNPKF)	67.9cd	63.7e	57.7ghij	63.IBC	10.6a	8.53cd	7.60gh	8.91A
W6xPsJN + (RNPKF)	67.7cd	59.4g	55.7hij	60.9D	9.60b	7.60gh	6.66ij	7.95B
W1OxPON + (RNPKF)	71.3bc	63.8e	55.1ij	63.4BC	9.73b	8.53cd	6.40jk	8.22AB
W6 xW1OxPON + (RNPKF)	75.5 a	65.1de	59.7fg	66.8A	10.6a	8.26cdef	8.00defg	8.95A
Mean	68.9A	61.7B	56.8C		8.99A	7.81B	6.80C	
	C				D			
Control + (RNPKF)	8.86 efg	7.97hi	7.18 ij	8.00E	31 m	27n	23o	27H
W6 + (RNPKF)	10.1bc	8.77fgh	8.07gh	9.04D	41 h	37 j	331	37 F
W10 + (RNPKF)	12.0a	9.91cd	8.29gh	10.1BC	38 i	35 k	331	35 G
PsJN + (RNPKF)	9.86cd	8.85efg	7.00 j	8.57D	43 g	39 i	35 k	39 E
W6xWIO + (RNPKF)	12.0a	10.0cd	9.31def	10.4B	49d	45f	41 h	45D
W6XPsJN + (RNPKF)	11.0b	10.0cd	9.33def	10.1BC	53 b	49 d	45 f	49 B
W1OxPsJN + (RNPKF)	10.8b	9.67cde	8.47gh	9.66C	51 c	47 e	43 g	47 C
W6xW1OxPsJN + (RNPKF)	12.7a	10.9b	9.87cd	11.2A	57a	53b	49d	53A
Mean	10.9A	9.52B	8.44C		45A	41B	37C	

W10×PsJN + RNPKF and W6× PsJN + RNPKF as compared to control.

Results showed that the interactive effect of PGPR with RNPKF at various levels of salinity stress (PGPR × EC) was

Table 3. Effect of multi-strain PGPR inoculation with recommended dose of NPK fertilizer (RNPKF) under various salinity levels (3, 6 and 9 dS m^{-1}) on wheat.

Inoculated PGPR strains	Electrical Conductivity of soil (dSm^{-1})							
	3	6	9	Mean	3	6	9	Mean
	A				B			
Control + (RNPKF)	0..6 0 lm	0.58n	054 no	0.57E	0.69c	0.35h-k	0.25l	0.43D
W6 + (RNPKF)	0.96b-e	0.81gh	0.63Id	0.80C	0.91b	0.44f-h	0.35h-k	0.56C
W10 + (RNPKF)	1.00b-d	0.78h-j	0.61lm	0.80C	0.91b	0.48f-h	0.31jk	0.56C
PsJN + (RNPKF)	0.95c-f	0.84f-h	0.58m	0.79D	0.98ab	0.49e-g	0.34i-k	0.60C
W6xW10 + (RNPKF)	1.07ab	0.90de	0.71i-k	0.89AB	0.99ab	0.53d-f	0.37g-k	0.63BC
W6xPsJN + (RNPKF)	1.06ab	0.85ef	0.64Id	0.85BC	1.02ab	0.61c-e	0.41 f-j	0.68AB
W1OxPsJN + (RNPKF)	1.05a-c	0.88ef	0.69jk	0.87AB	1.02ab	0.61c-e	0.41 f-j	0.68AB
W6xW1OxPON + (RNPKF)	1.13a	0.92d	0.73i-k	0.93A	1.08a	0.64cd	0.45 f-i	0.71A
Mean	0.98A	0.82B	0.64C		0.95A	0.51B	0.36C	
	C				D			
Control + (RNPKF)	17m	13p	9q	13G	27.6e	23.0h-j	21.0j	29.3E
W6 + (RNPKF)	24h	20k	16n	20E	30.3cd	25.3fg	23.3g-i	26.3D
W10 + (RNPKF)	22j	181	14o	18F	32.0c	24.7f-h	21.7ij	26.1D
PsJN + (RNPKF)	26g	23h	191	22D	32.0c	28.3de	24.3gh	28.2C
W6xWIO + (RNPKF)	29ef	26g	22 j	25C	35.3b	28.3de	26.7ef	30.1B
W6xPsJN + (RNPKF)	32c	28f	24h	28B	32.0c	30.3cd	28.0e	30.1B
W1OxPsJN + (RNPKF)	29e	26g	23ij	26C	32.0 c	30.7c	27.7e	30.1B
W6xW1OxPsJN + (RNPKF)	39a	35b	31d	35A	38.7a	31.0c	28.0e	32.6A
Mean	27.3A	23.6 B	19.8 C		32.5A	27.7B	25.1C	

Table 4. Effect of multi-strain PGPR inoculation recommended dose of NPK fertilizer (RNPKF)under various salinity levels (3, 6 and 9 dSm^{-1}) on wheat.

Inoculated PGPR strains	Electrical Conductivity of soil (dS m^{-1})							
	3	6	9	Mean	3	6	9	Mean
	A				B			
Control + (RNPKF)	3.67 c-e	3.33de	3.00e	3.33B	9.73i	8.33j	7.33j	8.46D
W6 + (RNPKF)	4.33a-c	4.33a-c	4.33a-c	4.33A	12.6b-d	11.9c-f	10.4hi	11.6BC
W10 + (RNPKF)	4.67ab	4.33a-c	4.33a-c	4.44A	12.9bc	12.2c-e	9.89i	11.7BC
PsJN + (RNPKF)	4.33a-c	4.33a-c	4.00b-d	4.22A	12.3b-e	11.0f-h	10.7g-i	11.3C
W6xW10 + (RNPKF)	5.00a	4.33a-c	4.00b-d	4.44A	13.0bc	12.7b-d	11.0f-h	12.2B
W6xPsJN + (RNPKF)	4.67ab	4.33a-c	4.33a-c	4.44A	12.7b-d	11.7d-g	11.0f-h	11.7BC
W1OxPsJN + (RNPKF)	4.33a-c	4.33a-c	4.00b-d	4.22A	13.0bc	11.7d-g	11.0f-h	11.9BC
W6xW1OxPsJN + (RNPKF)	5.00a	4.67ab	4.33a-c	4.67A	15.1a	13.3b	11.3e-h	13.2A
Mean	4.50A	4.25AB	4.04B		12.7A	11.6B	10.3C	
	C				D			
Control + (RNPKF)	14.3k1	14.7k	12.3m	13.7F	48mn	40o	32p	40H
W6 + (RNPKF)	22.0b	18.0f-h	14.3Id	18.1CD	65hi	57k	50m	57F
W10 + (RNPKF)	15.7i-k	15.3jk	15.3Id	15.4E	61 j	531	47n	53G
PsJN + (RNPKF)	18.7e-g	15.0jk	14.3k1	16.0E	69g	62j	541	61E
W6xW10 + (RNPKF)	20.7b-e	17.0 g-j	16.3h-k	18.0D	79d	71fg	63ij	71D
W6xPsJN + (RNPKF)	22.7ab	19.0d-g	18.3f-h	19.2B	85c	75e	70g	76B
W1OxPsJN + (RNPKF)	21.7bc	18.7e-g	17.6f-i	19.3BC	80d	73of	66h	73C
W6xW1OxPsJN + (RNPKF)	24.3a	21.0b-d	19.6 c-f	213A	97a	88b	80d	88A
Mean	19.2A	17.3B	16.0 C		73A	MB	57C	

non-significant for a number of tillers per spike and spikelets per spike but significant for the number of grains per spike and biological yield (Table 4). Among all the treatments, W6×W10×PsJN + RNPKF performance was the best which significantly enhanced no. of tillers per spike (40%), no. of grains per spike (58%), spikelets per spike (56%) and biological yield (120%) as compared to control. However, in the case of the number of tillers per spike all PGPR treatments were statistically alike with each other but significantly different as compared to control (RNPKF). Although, the performance of multi strains inoculation with RNPKF was better at 6 and 9 dSm^{-1} EC but significant improvement was observed at EC 3dSm^{-1}. However, the number of tillers per spike showed statistically similar results but spikelets per spike, no. of grains per spike and biological yield results were ominously different at 3 and 6 $dSm^{-1.}$

Regarding nitrogen (Fig. 1, 2) and phosphorus (Fig. 3, 4) concentration in shoot and grains of wheat plants the statistical analysis exposed that the main and interactive effects of PGPR at various levels of salinity (PGPR × EC) with RNPKF were significantly different. As compared to control, the maximum nitrogen concentration in grains and shoot was observed in W6×W10×PsJN + RNPKF at 3 dS m-1 EC which was significantly different to all other treatments. However, W6×W10 + RNPKF and W6×W10×PsJN + RNPKF were statistically similar and performed best in increasing the phosphorus concentration in wheat grains. In the case of the shoot, the maximum increase in phosphorus concentration was observed in W6 + RNPKF and W6×W10×PsJN + RNPKF treatments which were also statistically alike with each other but significantly different as compared to control.

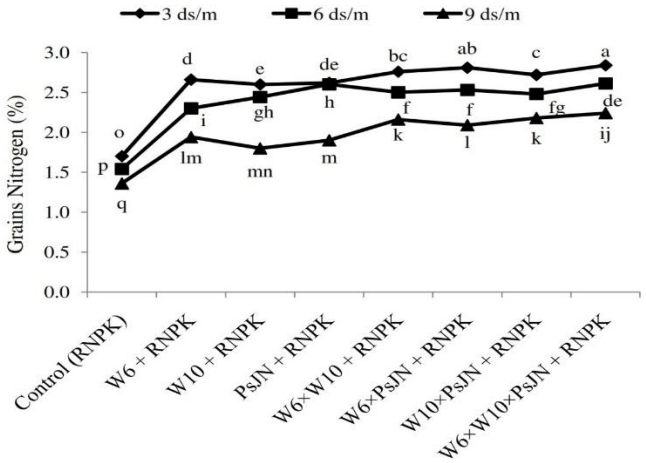

Figure 1. Effect of inoculated PGPR multi strains (W6, W10, PsJN) with recommended dose of NPK fertilizer (RNPKF) on grains nitrogen (%) of wheat (*T. aestivum L.*) grown under 3, 6 and 9 dSm^{-1} salinity levels. Lines represent mean values of 3 replicates. Different letters on bars and lines show statistical differences at $P \leq 0.05$.

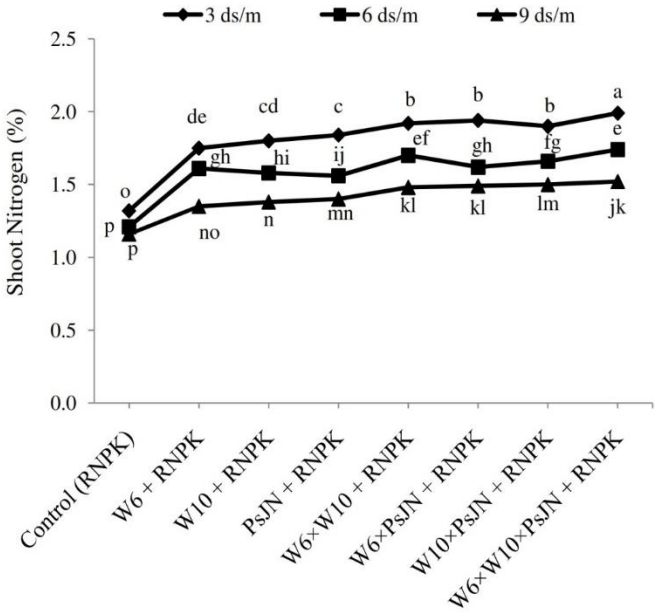

Figure 2. Effect of inoculated PGPR multi strains (W6, W10,PsJN) with recommended dose of NPK fertilizer (RNPKF) on shoot nitrogen (%) of wheat (*T. aestivum L.*) grown under 3, 6 and 9 dS m^{-1} salinity levels. Lines represent mean values of 3 replicates. Different letters on bars and lines show statistical differences at $P \leq 0.05$.

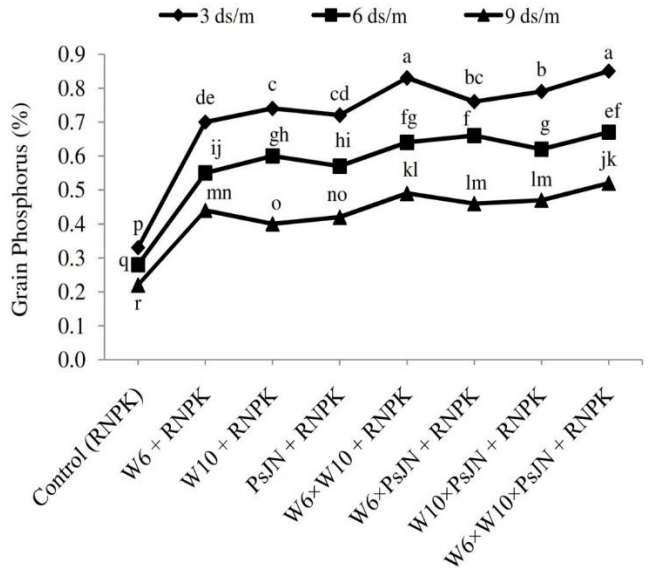

Figure 3. Effect of inoculated PGPR multi strains (W6, W10,PsJN) with recommended dose of NPK fertilizer (RNPKF) on grain phosphorus (%) of wheat (*T. aestivum L.*) grown under 3, 6 and 9 dS m^{-1} salinity levels. Lines represent mean values of 3 replicates. Different letters on bars and lines show statistical differences at $P \leq 0.05$.

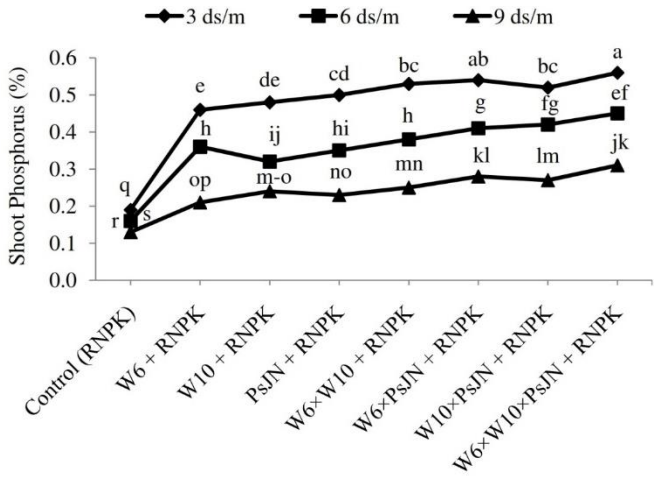

Figure 4 Effect of inoculated PGPR multi strains (W6, W10,PsJN) with recommended dose of NPK fertilizer (RNPKF) on shoot phosphorus (%) of wheat (*T. aestivum L.*) grown under 3, 6 and 9 dS m^{-1} salinity levels. Lines represent mean values of 3 replicates. Different letters on bars and lines show statistical differences at $P \leq 0.05$.

DISCUSSION

Salt stress increases ethylene concentration in plants, resulting in adverse effects on growth and yield (Burd *et al.,*1998; Cuartero and Fernandez-Munoz, 1999). Direct or indirect application of ethylene in plants mostly showed negative impacts on the growth attributes (Guinel and Sloetjes, 2000). In our study under salinity stress multi-strain ACC-deaminase PGPR inoculation with RNPKF, ominously amended the growth and yield traits (biological, straw plus economic) in wheat plants which might be due to less endogenous accretion of ethylene that subsequently affect the roots elongation positively (Table 2, 3, 4). The verdicts of Glick *et al.* (1999) also braced the argument as they perceived a significant diminution in the accretion of ethylene due to its breakdown into ammonia (NH_3) and α-ketobutyrate by the enzymatic activity of ACC deaminase PGPR. Similarly, a number of researchers also observed the same results after inoculation of ACC deaminase under different abiotic stresses (Belimov *et al.,* 2002; Nadeem *et al.,* 2009; Naz *et al.,* 2013; Zafar-ul-Hye *et al.,* 2014; Kiani *et al.,* 2015).

In another trial, Patten and Glick (2002) noted well elongation of root in canola seedlings (35-50%) which were inoculated with IAA secreting PGPR as compared control (no PGPR). They argued that the secretion of indole acetic acid (IAA) by ACC-deaminase PGPR promotes the division of cell which might be the main cause of root elongation in canola seedlings (Etesami *et al.,* 2014). Zahir *et al.* (2009) applied ACC deaminase PGPR in combination with rhizobia and noted a significant enhancement (196%) in the modulation of lentil as compared to control. In one of *experiments* Zafar-ul-Hye *et al.* (2015) also reported that the Pseudomonas bacterial strains had the capability to enhanced root length in maize plants up to 34% without inorganic fertilizer and 108% with inorganic fertilizer as compared to control (no PGPR).

Our results also showed the better uptake of nitrogen (Fig. 1 and 2) and phosphorus (Fig. 3 and 4) nutrients in the grains and shoot of wheat plants cultivated at various levels of salinity stress. This improvement in N and P concentrations might be due to better elongation of roots as well as secretion of growth hormones by PGPR that ultimately solubilized the immobile P. Wu *et al.* (2005) suggested that the secretion of PGR such as auxins and gibberellins (Holl *et al.,* 1988; Remans *et al.,* 2008; Guiñazú *et al.,* 2010) by PGPR might be an important factor that played a crucial role for better water and nutrients intake in crops. Han and Lee (2006) in their study noted that the P and K which were applied in the form of rock did not enhance the available potassium (K) and phosphorus (P) of soil. However, inoculation of K and P solubilizing PGPR significantly enhanced the available P (36%) and K (31%) of soil for pepper and cucumber plants as compared to control (no PGPR). The better uptake of P and N in the current study may be attributed as an important factor regarding significant improvement in fresh and dry weight of root and shoot, economic, biological and straw yields as well as 1000-grains weight in wheat plants (Table 3). According to Richardson *et al.* (2009), better accessibility of P promotes the root elongation which ultimately helps in enhancing the dry weight in crops through better nutrition. The results of Amanullah and Inamullah (2016) also support the better dry matter production due to the efficient use and availability of P in rice plants. However, Mandic *et al.* (2015) argued that better N use efficiency is one of the major factors that enhanced the productivity of wheat. The consequences of Hassan *et al.* (2015) also support the fact of better growth in wheat plants through ACC deaminase PGPR inoculation.

***Conclusion*:** It can be concluded from the results that the use of single and multi-strains ACC deaminase PGPR with RNPKF is a novel approach to enhance the growth traits and notable nutrients uptake in wheat plants under salinity stress. However, it is fascinating to note that although ACC deaminase PGPR enhanced growth and yield traits in wheat when used alone, their multi-strain inoculation (W6×W10×PsJN) further improved the synergistic effect in the presence of PNPKF to mitigate the salinity stress in wheat.

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